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A Study of Nutrients and Trace Elements in an Agricultural Watershed

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ABSTRACT

The amounts of trace elements and nutrients released by commercial fertilizers were examined in southern Saskatchewan in 1984 and 1985. Fertilizer use patterns were determined for 2800 hectares of agricultural land. Soils and fertilizers were analyzed for trace elements to assess the potential contamination of soils from these trace elements. Nitrogen and phosphorus concentrations in spring runoff, surface waters and atmospheric deposition were measured from which the inputs of nutrients into two sloughs were estimated.

Fertilizers do not result in a significant addition of trace elements to soils. Total nitrogen and total phosphorus inputs into the sloughs from spring runoff comprised less than 1.5% of the nitrogen and phosphorus that were applied as fertilizers over the drainage area. Total nitrogen and total phosphorus in wet and dry precipitation averaged 1.91 $mg/m^2/day$ and 0.15 $mg/m^2/day$ respectively. Nutrients in agricultural runoff and atmospheric deposition can produce surface waters with nitrogen and phosphorus concentrations similar to those found in eutrophic Saskatchewan lakes.

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1 INTRODUCTION

This report examines the amount of nutrients in agricultural runoff contributed by commercial fertilizers and the potential contamination of soils by trace elements in fertilizers. Nutrient levels in wet and dry precipitation were also measured, since atmospheric deposition can be a significant source of nutrients in agricultural runoff (Schuman and Burwell 1974; Taylor et al. 1971).

Concerns over deteriorating water quality from nonpoint sources have resulted in numerous studies of nutrient losses via agricultural runoff, particularly nitrogen and phosphorus, since both elements stimulate algae and weed growths in surface waters (Burwell et al. 1975; Dunigan et al. 1976; Sharpley and Syers 1983). Many of these studies have been conducted in the United States, where climatic conditions and agricultural practices often differ from those in southern Saskatchewan. Commercial fertilizer usage in Saskatchewan has grown from a mere 10,000 tonnes to over 670,000 tonnes between 1946 and 1983 (Alberta Agriculture 1984), but little information has been reported on its effect on water quality. Information that is available applies to the movement of nutrients off field plots (Nicholaichuk and Read 1978) but not for larger areas such as watersheds. The long-term use of commercial phosphate fertilizers has also given rise to concern for the potential

accumulation of Cd and other trace elements in soil (Bignoli and Sabbioni 1981; Khan et al. 1981; Williams and David 1973). The potential trace element contamination of Saskatchewan soils by fertilizers has also not been reported. Therefore, a study in southern Saskatchewan was conducted to obtain data on these potential fertilizer impacts. Data were collected on fertilizer use patterns, trace element concentrations in soils and fertilizers, and nutrient concentrations in spring runoff, surface water, ground water, and atmospheric deposition.

2 METHODS

2.1 Description of Study Area

The primary study area (Site 1) is located 25 km north of the City of Regina on clay soil (Figure 1). This site, described by Waite et al. (1986), encompasses 2800 hectares which has been dryland farmed for generations. Two permanent, interconnected sloughs drain 648 ha. within Site 1 and an additional area upstream. The surface areas of the lower and upper sloughs were 0.6 ha. and 1.7 ha. respectively, and their mean depths were 0.5 m and 1.0 m respectively (Waite et al. 1986). Water levels in the sloughs fluctuate with the seasons and from year to year as is normally the situation for sloughs in southern Saskatchewan. Upstream water entering the study area was monitored as it passed through several road culverts

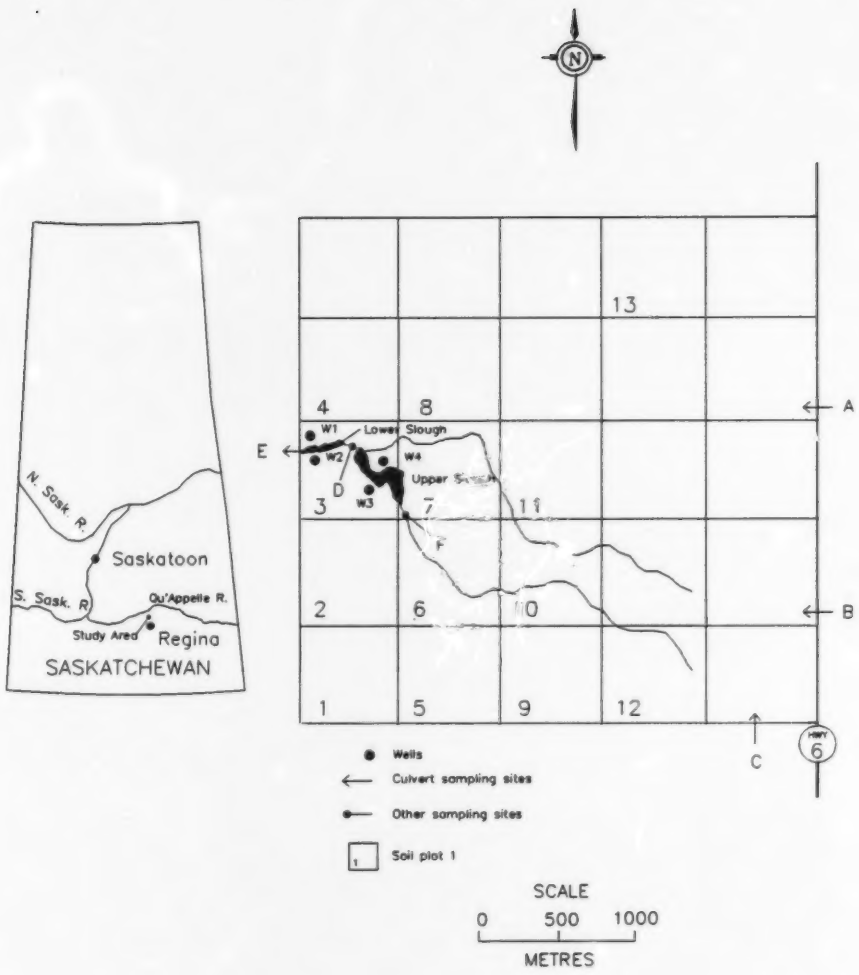

Figure 1 Water and Soil Sampling Locations Within Site 1

(Figure 1). Spring Wheat was the main crop grown in the study area. This study area was used to obtain data on fertilizer use patterns, trace element concentrations in soils, and nutrient concentrations in spring runoff, surface water, ground water, and atmospheric deposition.

A 4.8 hectare parcel of farmland, seven km to the southeast of Site 1, was sampled to supplement trace element data for clay soils which predominate the Regina area.

Spring runoff in southern Saskatchewan has been low in recent years, and the runoff in 1985 was no exception, despite the near normal levels of precipitation. Total snowfall in 1984 and 1985 was 121.9 cm and 104.1 cm respectively; the average between 1951 and 1980 was 115.7 cm. Total rainfall in 1984 and 1985 was 17.66 cm and 28.53 cm respectively; the average between 1951 and 1980 was 28.72 cm. The last seven continuous days of 2 cm of snow cover in 1984 and 1985 ended on March 20 and March 13 respectively, compared to March 29, on average, for the period between 1951 and 1980. The data were collected at the Regina airport.

2.2 Field Methods

2.2.1 Soil

In November 1984, composite soil samples were collected

from 13 plots at Site 1 (Figure 1) using a 1.27 cm diameter Oakfield sampler. Plots 1-12 were established on cultivated lands which have been subject to long-time fertilization practices, in contrast to Plot 13 which has been owned and operated by the City of Regina, since 1930, as a well site. Plot 13 has also been used as pasture land. Twenty cores, 30 cm in depth, were collected from two parallel transects along the center of each plot. The ten cores from each transect were composited. Twenty-six composite samples were produced, and eight of these were split in the field for quality control purposes.

In September 1987, 108 core samples were collected from Site 2 using a hydraulic, truck mounted corer which was 5.1 cm in diameter. The cores, 15 cm in depth, were collected along six transects over 4.8 hectares. Eighteen cores from each transect were composited. Six composite samples were produced, and three of the composites were split in the field for quality control purposes.

2.2.2 Water

Surface runoff samples were collected daily between March 28 and April 3, 1985, at Stations A-E (Figure 1). Grab samples were collected in polyethylene bottles. Prior to shipment, the nitrogen and phosphorus samples were respectively preserved with H_2SO_4 (Environment Canada 1983) and ice. A Price 625 pygmy flow meter was used once each

day to measure water velocities through the culverts.

Grab samples of water were collected weekly between June 11 and July 02, 1985, from three ABS stand pipes and the two sloughs (Figure 1). A fourth stand pipe was sampled once. Holes were augured into the water table, which was found at depths of 2.75 m and 1.50 m, respectively, near the upper and lower sloughs. Sand was placed in the bottom of the holes, which were backfilled with sand and bentonite upon placement of the pipes. Samples were pumped into polyethylene bottles. Ground and surface water samples were preserved in the same manner as the runoff samples.

2.2.3 Precipitation

Precipitation samples were collected weekly between May 7 and June 12, 1984, and between May 1 and July 2, 1985. Two precipitation collectors were fabricated, as described by Waite et al. (1986), and located adjacent to the lower slough. Each collector had a 1 m^2 sheet metal tray with 15 cm sides and a drain hole in the center of the tray. A sample bottle was located underneath each collector, and the bottle mouth was wrapped with aluminum foil to prevent evaporation. Precipitation was measured with a rain gauge. If no precipitation fell during the week, the trays were washed down with 4 L of distilled, deionized water which was collected as the dry precipitation sample. If less than 4 mm of precipitation fell during the week, the trays were washed

with 4 L of distilled, deionized water which was combined with the collected precipitation to produce the wet-dry precipitation sample, but if more than 4 mm of precipitation fell over the week, no wash water was used to collect the wet sample. All samples were transferred into polyethylene bottles and preserved in the same manner as the runoff samples.

2.2.4 Fertilizers

Information on the amount and type of fertilizers applied on Site 1 during 1984 and 1985 was obtained through personal interviews with the farmers. Grab samples of four granular fertilizers were collected from four retail outlets. A composite of each product was produced, and two of the composites were split in the field. All samples were kept in Whirl Pacs®.

2.3 Laboratory Methods

2.3.1 Water

Water samples were analyzed by the Environmental Protection Laboratory for: 1) conductivity (American Public Health Association (APHA) 1980, method 205); 2) NH_4-N (APHA 1980, method 417 A); 3) NO_2-N and NO_3-N (EPA 1979, method 353.2); 4) total kjeldahl nitrogen (APHA 1980, method 420 B); and 5) total phosphorus (EPA 1979, method 365.1).

Site 1 soil samples and fertilizer product samples were analyzed by the Sherritt Research Centre of Sherritt Gordon Mines Ltd. in Fort Saskatchewan, Alberta for: Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, Se, Si, U, V, Zn. A sodium carbonate and sodium peroxide fusion digestion was used, and the extracts were analyzed by inductively coupled plasma mass spectroscopy.

Site 2 soil samples were analyzed by the Environmental Protection Laboratory in Edmonton, Alberta, for: As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se, and Zn. Except for Hg, the samples were freeze dried, passed through a 2 mm sieve and sequentially digested with nitric, perchloric and hydrofluoric acids (Environment Canada 1979, open digestion). The Hg samples were freeze dried, digested with 5 ml of Aqua Regia followed by 15 ml of 5% potassium permanganate solution in a hot water bath (95°C). Mercury was analyzed by a manual cold vapor Hg analyzer, and As and Se were analyzed by hydride generation. The remaining elements were analyzed by flame atomic absorption spectroscopy. The elements were analyzed in accordance with the following methods: 1) As (EPA 1983, method 206.3); 2) Cd (EPA 1983, method 213.1); 3) Co (EPA 1983, method 219.1); 4) Cr (EPA 1983, method 218.1); 5) Cu (EPA 1983, method 220.1); 6) Hg (EPA 1983, method 245.5); 7) Ni (EPA 1983, method 249.1); 8) Pb (EPA 1983, method 270.3), 9) Se (EPA 1983, method 270.3); and 10) Zn (EPA 1983, method 289.1).

2.3.2 Quality Control

The quality control program consisted of the analysis of replicate samples for precision and the analysis of sediment standards for accuracy. Precision was expressed by the average of the coefficients of variation, and accuracy was expressed by the average of the relative errors (APHA 1980).

Eight soil samples replicated in the field and analyzed by the Sherritt Research Centre resulted in average coefficients of variation above 25% for As, B, Co, Mo, Na and Pb. The concentration of Cd, Hg, Se and Zn in these samples were less than detectable. Two fertilizer samples replicated in the field and analyzed by this laboratory resulted in coefficients of variation above 25% for As. The concentrations of Cu, Hg, Se and Si in the replicates were less than detection. The analysis of two NBS standards resulted in relative errors in excess of 25% for Cr, Cu, Co, K, Mn, Na, Ni, Si and V. The concentrations of Hg and Se in these standards were below detection.

The quality control results reported by the Environmental Protection Laboratory are presented below. The analysis of three samples replicated in the field resulted in average coefficients of variation below 25% for all the elements except Hg. The analysis of two samples triplicated in the laboratory resulted in average coefficients of

variations below 25% for all the elements. The analysis of one NBS standard resulted in relative errors below 25% for all the elements except Cr and Se.

3 RESULTS AND DISCUSSION

3.1 Trace Elements in Soils and Fertilizers

To assess the accumulation of trace elements in soil from fertilizers, data were collected on fertilizer usage rates and trace element concentrations in soils and fertilizers. These data were used to calculate the number of fertilizer applications required to double existing trace element concentrations in the soil.

Concentrations of 22 trace elements in Site 1 soil are shown in Appendix 1. Seven elements (B, Cd, Co, Cu, Hg, V and Zn) show large variations within and between plots. Most of the boron concentrations were less than 15 ug/g, with many below the detection limit of 6 ug/g. Plots 10 and 11 contained 90 and 85 ug/g of B, respectively, in one of their two samples but contained less than 6 ug/g in the other sample. Cobalt values were mostly below 30 ug/g, but two abnormally high concentrations were reported for Plots 2 and 11. Many of the Cu and Hg values were below detection. Most of the high Cu values occurred in paired samples (Plots 10 - 13) unlike the high values for Hg. Four plots contained less-than-detectable concentrations of V in one of their two

samples but contained between 112 - 225 ug/g in their other sample. Less-than-detectable concentrations of V were found in both samples from Plot 9. A discrepancy in the Zn data was apparent by the less-than-detectable values (<5 ug/g) in one of the two samples from Plots 3, 6 and 8 compared to high concentrations, that ranged between 135 and 358, in the second samples.

Concentrations of ten trace elements for Site 2 soils are shown in Appendix 2. The variations of the parameters between transects are relatively small, and no extreme range of values is evident, unlike the data shown in Appendix 1 for the same parameters. The trace element median concentrations observed at Site 2 are similar to concentrations found in Saskatchewan soils, and together with the medians for the other parameters (Appendix 1), these data represent trace element concentrations in the study area (Table 1).

Fertilizer use patterns within Site 1 are presented in Table 2. Urea (46-0-0), Monoammonium Phosphates (11-48-0, 11-51-0, 11-55-0), and Urea and Ammonium Phosphate blends were the predominant forms of fertilizers used in both years. Most of these fertilizers were mixtures of nitrogen (N) and phosphate (P_2O_5) with no potash (K_20), which reflects the K sufficiency of southern Saskatchewan soils. Although fertilizer consumption was higher in 1984 than in 1985 (164 vs 133 tonnes), the average fertilizer application rate for

both years was 93 kg per hectare (Table 2).

Four fertilizers commonly used in Site 1, representing a cross section of N and P_2O_5 blends, were analyzed for the same 22 trace elements as the soil (Table 3). Most of the higher trace element concentrations appear to be associated with the high P_2O_5 content fertilizer (11-51-0). The phosphatic rock, which is leached in the manufacture of P_2O_5 fertilizers, is the likely source for these higher trace element concentrations.

Table 1

Trace Element Concentrations in Study Area Soils[a]

Parameter	Median[b]
Al	62200[c]
As	10.7[d]
B	<6[c]
Ca	16000[c]
Cd	<2[d]
Co	13.8[d]
Cr	99.8[d]
Cu	32.3[d]
Fe	29800[c]
Hg	0.016[d]
K	8175[c]
Mg	11400[c]
Mn	597[c]
Mo	1[c]
Na	685[c]
Ni	33.4[d]
Pb	13.2[d]
Se	0.62[d]
Si	221000[c]
U	1[c]
V	119[c]
Zn	113.5[d]

a Site 1 and 2 data from Appendices 1 & 2
b ug/g dry wt.
c Site 1 data
d Site 2 data

Table 2

Fertilizer Use in Study Area

1984			1985		
Fertilizer	Area (ha.)	Amount (kg)	Fertilizer	Area (ha.)	Amount (kg)
11-48-0	60	2,964	11-34-0	44	4,996
11-51-0	242	12,230	11-51-0	416	21,946
11-55-0	441	23,117	11-52-0	71	2,141
18-48-0	111	6,238	11-55-0	134	7,462
26-13-0	45	2,527	26-26-0	39	1,810
27-27-0	48	5,387	34-00-0	87	4,402
33-17-0	32	3,594	34-17-0	368	54,146
34-15-0	262	45,391	46-00-0	221	27,429
46-00-0	520	62,667	55-25-0	58	9,079
Total:	1,761	164,115		1,438	133,411
Avg. (kg/ha.):		93			93
Total N (kg)		52,894			42,008
Total P (kg)		16,027			14,788

Table 3

Trace Element Concentrations

in Commercial Fertilizers (ug/g dry wt.)

Parameter	46-0-0[a]	11-51-0[a]	27-27-0[b]	34-17-0[b]
Al	27	10285	5667	3619
As	2	14	5	4
B	5	48	8	16
Ca	669	8970	4980	3211
Cd	<1	179	3	<1
Co	<1	4	3	1
Cr	<2	727	56	34
Cu	<5	<5	19	<5
Fe	283	7106	6233	3432
Hg	<3	<3	<3	<3
K	110	1860	700	720
Mg	31	6551	2267	1548
Mn	<3	70	194	77
Mo	<1	19	6	3
Na	81	2719	870	932
Ni	7	179	35	17
Pb	36	12	5	18
Se	52	<40	61	<40
Si	<5	<5	<5	<5
U	<1	50	93	61
V	<10	1106	74	46
Zn	13	1668	93	46

a average of one split, composite sample

b one composite sample

Due to the detrimental health effects of cadmium at low concentrations, this trace element is of most concern in fertilizers. Cadmium levels for 11-51-0 (Table 3) are higher than Cd levels for phosphate fertilizers in literature reviewed by Webber (1979). Data for 30 Canadian fertilizers indicate a Cd range between 2 and 91 ug/g (Crober 1978 from Webber 1979).

The estimated contribution of fertilizer trace elements to the soil was based on an application of 11-51-0, the fertilizer containing the highest concentration of trace elements, at 50 kg per hectare. The number of applications required to double the trace element concentrations in soil above those reported in Table 1 are presented in Table 4. For this calculation, trace elements less than detectable (Table 1) were assigned values one-half of their detection limit. Data in Table 4 show that trace elements added to the soil contribute to background levels only after many applications. Therefore, trace elements in fertilizers do not pose a concern.

3.2 Water Quality and Precipitation

Nutrient concentrations observed in spring runoff, surface water (sloughs) and ground water are shown in Table 5. The runoff concentrations were relatively consistent at all the stations. Total kjeldahl nitrogen was the predominant form of nitrogen in the runoff while nitrate

Table 4

Number of Applications of 11-51-0 Fertilizer Needed to Double Trace Element Concentrations in Study Area Soils[a]

Al	266,701
As	33,705
B	2,756
Ca	78,662
Cd	246
Co	152,145
Cr	6,054
Cu	569,772
Fe	184,939
Hg	470
K	193,827
Mg	76,742
Mn	376,110
Mo	2,321
Na	11,110
Ni	8,229
Pb	48,510
Se	1,367
Si	3.9×10^9
U	882
V	4,745
Zn	3,001

a 50 kg/ha and incorporated into the top 15 cm of soil

concentrations were above the range of 0.049 to 0.170 mg/L reported for snowmelt from the Precambrian shield of northern Saskatchewan (Shewchuk 1982). The nutrient concentrations in the runoff were similar to nutrient concentrations reported downstream, over the same period, in the Qu'Appelle River above Pasqua Lake (Munro 1986). Total nitrogen (TN) and total phosphorus (P) concentrations observed in the runoff exceeded Saskatchewan's "Water Quality Objectives (1975)." Nitrogen and P concentrations in spring runoff from fertilized and unfertilized fields have also been observed in excess of these objectives (Nicholaichuk et al. 1978).

Since runoff into the sloughs exceeded the volumes of the upper and lower sloughs by 18% and 1800% respectively, water quality in the sloughs immediately following spring runoff was assumed to be similar to the quality of the runoff. By midsummer, the water quality was different from that of the spring runoff. The largest difference occurred in the NO_3-N concentrations which were lower in both sloughs, likely as a result of denitrification. Conductivity values for the lower slough were higher, generally by five-fold, than those for the upper slough. This indicates the presence of ground water in the lower slough, and the resulting dilution of this slough water may account for the observed decrease in P compared to spring runoff concentrations. Low nitrogen concentrations in the ground water (Table 5) indicate that large amounts of NO_3-N from

Table 5

Water Quality Results[a]

Spring Runoff (seven grab samples, March 28 - April 3, 1985)

Location	TKN	NH_3-N	NO_2-N	NO_3-N	P	Conductivity (umhos/cm)
Sta. A	1.08[b] (0.90-1.20)[c]	0.01 (<0.01-0.03)	0.01 (0.01-0.02)	0.45 (0.25-0.73)	0.43 (0.38-0.49)	NV[d]
Sta. B	1.02 (0.86-1.20)	0.01 (<0.01-0.04)	0.01 (<0.01-0.02)	0.53 (0.25-0.84)	0.22 (0.19-0.24)	NV
Sta. C	1.16 (0.91-1.50)	0.03 (<0.01-0.09)	0.02 (0.010-0.030)	0.90 (0.39-1.61)	0.23 (0.18-0.29)	NV
Sta. D	1.12 (0.96-1.30)	0.05 (0.02-0.10)	0.02 (0.01-0.03)	0.60 (0.33-1.16)	0.32 (0.29-0.34)	NV
Sta. E	1.14 (0.99-1.30)	0.06 (<0.01-0.11)	0.02 (0.01-0.03)	0.56 (0.34-0.97)	0.32 (0.30-0.34)	NV
Surface Water (4 grab samples, June 11-July 2 1985)						
Lower Slough	2.20 (1.93-2.55)	0.20 (0.15-0.24)	<0.01 (<0.01)	0.01 (<0.01-0.02)	0.11 (0.02-0.19)	2593 (2300-2800)
Upper Slough	1.53 (1.32-1.67)	0.17 (0.14-0.22)	0.01 (<0.01-0.02)	0.01 (<0.01-0.02)	0.34 (0.23-0.46)	560 (550-570)
Ground Water (4 grab samples, June 11-July 2 1985)						
Well 1	0.89 (0.77-1.00)	0.09 (0.06-0.11)	<0.01 (<0.01)	0.88 (0.81-0.95)	0.03 (<0.01-0.06)	2645 (2330-2900)
Well 2	1.22 (1.06-1.45)	0.28 (0.18-0.38)	0.01 (<0.01-0.01)	0.95 (0.81-1.07)	0.03 (<0.01-0.05)	4237 (4100-4400)
Well 3[e]	54.5	1.51	<0.01	0.03	<0.01	4700
Well 4	6.13 (1.95-16.6)	2.04 (0.35-6.07)	0.03 (<0.01-0.07)	15.8 (14.4-17.6)	0.06 (<0.01-0.11)	4328 (4115-4550)

a mg/L unless noted
b average
c range
d no value reported
e one sample

fertilizers have not infiltrated the ground water.

The amounts of NO_3-N (50.6 kg) and P (22.2 kg) in the runoff entering both sloughs were estimated from daily flow measurements obtained at Stations D and F, assuming eight hours of daily flow. The nutrient loading at Station F was based on nutrient data collected at Station C. These amounts corresponded to 1.4% and 1.5 % of the N (3700 kg) and P (1500 kg) applied in the fall of 1984 on the 648 hectares that drain into the sloughs. The portions of N and P in the runoff derived from fertilizers are lower than the above percentages since the above inputs include sources, besides fertilizers, such as sediments and snowmelt, and runoff originating upstream of the study area. Fertilization accounts for less than 15% of the N and P observed in agricultural runoff (Alberts et al. 1978; Dunigan et al. 1976; Kilmer et al. 1974; Moe et al. 1967). Nicholaichuk and Read (1978) reported fertilizer P losses of 9.8% in spring runoff; however, the fertilizer was applied in late fall on the surface of frozen summerfallow. Spring runoff represents over 85% of the total runoff from agricultural watersheds in western Canada (Nicholaichuk 1967); therefore annual losses of soluble N and P from fertilizers to surface waters are most likely to occur during this period.

Using Table 5 data for the sloughs together with the slough surface volumes and mean depths (Section 2), the estimated loadings of total nitrogen and P in the upper

slough were 29.24 kg and 5.78 kg respectively, while the total nitrogen and P loadings in the lower slough were 7.24 kg and 0.33 kg respectively.

Besides the contribution of nutrients into the sloughs from spring runoff, atmospheric deposition was the other major external source; seasonal rainfall contributed minimal runoff to the sloughs. Atmospheric deposition data for 1984 and 1985 are presented in Table 6. The deposition rates for both years were similar. The atmospheric P deposition loadings were within the range of 0.1 and 1.0 kg/ha./yr (0.03 to 0.27 $mg/m^2/day$) found in the literature (Chapin and Uttormark 1973). Deposition of NO_2-N and NO_3-N measured 0.41 $mg/m^2/day$ (1.50 kg/ha./yr). In comparison, limited data for the midwest United States show NO_2-N and NO_3-N concentrations in rainfall between 0.5 and 1.5 kg/ha/yr (Chapin and Uttormark 1973). Dry fallout has been estimated to account for 40% to 90% of the nitrogen input (Hoeft 1971; Kluesener 1972; from Chapin and Uttormark 1973). The TKN in the samples comprised 78.5% of the total nitrogen; this portion is attributed to the high amount of dustfall collected.

Based on the average nutrient deposition rates shown in Table 6, the amount of N and P deposited on 1438 hectares over the seasonal period for wet and/or dry precipitation (April - September) represents 11.9% and 2.6%, respectively, of the 42,008 kg of N and 14,788 kg of P applied as

Table 6

Atmospheric Deposition Rates of Nutrients ($mg/m^2/day$)[a]

Date	Type	TKN	NO_2-N	NO_3-N	TP
(1984)					
May 07	wet	0.81	<0.01	0.44	0.07
May 15	wet	2.41	0.02	0.89	0.58
May 22	wet[b]	1.68	<0.02	0.81	0.20
May 29	dry[c]	3.09	0.01	0.16	-[d]
June 05	dry[c]	0.80	0.01	0.24	0.16
June 12	wet	0.37	<0.01	0.23	0.02
(1985)					
May 01	dry	0.77	<0.01	0.14	0.06
May 07	wet	2.00	<0.01	0.44	0.11
May 14	wet	1.62	<0.04	0.48	0.17
May 21	dry	0.42	<0.01	0.08	0.35
May 29	wet	1.71	0.01	0.78	0.13
June 04	wet	2.98	<0.22	0.54	0.22
June 11	wet	1.80	<0.02	0.40	0.04
June 18	wet	1.49	<0.02	0.32	0.03
June 25	wet/dry	1.02	<0.01	0.25	0.09
July 02	wet/dry	1.00	<0.01	0.09	0.07
	Avg.	1.50	0.02	0.39	0.15

a average of south and north collectors unless noted

b south collector

c combined sample

d sample lost

fertilizer in 1985 (Table 2). Most of the N was not immediately available to plants (NO_3-N) since it was in the TKN form. Over this period, atmospheric deposition contributed approximately 5.94 kg of total nitrogen and 0.47 kg of P to the upper slough and 2.09 kg of total nitrogen and 0.16 kg of P to the lower slough.

Nutrient loadings into the sloughs from the atmosphere, determined from average daily inputs (Table 6) over the April to June period, and the summertime nutrient loadings in the sloughs, estimated from data in Table 5, are shown in Table 7. These data show that N deposition respectively comprised 14% and 10% of the total nitrogen loading observed in the lower and upper sloughs, while P deposition respectively comprised 24% and 4% of the P loading observed in the lower and upper sloughs. The relatively higher P fraction in the lower slough may be attributed to this slough's higher surface area to volume ratio and its low concentration of P (Table 5).

Although nutrient losses in spring runoff were not agronomically significant, these amounts together with inputs from atmospheric deposition can produce nutrient concentrations in surface waters that are similar to those in the Fishing Lakes of the Qu'Appelle River System, which have been widely reported as eutrophic (Allan and Kenney 1978; Allan et al. 1980). The results (Table 5) show that surface waters originating from agricultural runoff will

exceed Saskatchewan's "Water Quality Objectives". Some surface waters in southern Saskatchewan, which were eutrophic prior to the arrival of early explorers (Allan et al. 1980), receive agricultural runoff. Unfortunately, nutrient control of agricultural runoff and other nonpoint sources is not feasible; therefore, the current strategy of controlling nutrient loadings into these waters from municipal sewage and other point sources will likely continue.

Table 7

Comparison of Total Nutrient Loadings and Atmospheric Nutrient Loadings in Sloughs

	Total Loading[a,b]		Deposition Loading[a,c]	
	TN	P	TN	P
Lower Slough	7.24	0.33	1.04	0.08
Upper Slough	29.24	5.78	2.95	0.23

a kg

b Based on N and P averages in Table 5

c Table 6 data projected over April-June

4 CONCLUSIONS

Commercial fertilizers do not add significant amounts of trace elements already present in the soil. Spring runoff

from Saskatchewan farmland can contain N and P at concentrations that exceed Saskatchewan's "Water Quality Objectives (1975)" as previously reported by Nicholaichuk and Read (1978). Spring runoff contributed more N and P to surface waters in the study area than did atmospheric deposition. Nitrogen and P in spring runoff represented less than 1.5% of the N and P that were applied on the study area in the fall of 1984. Although nutrient losses in spring runoff were not agronomically significant, these losses along with atmospheric deposition produced surface waters with N and P concentrations that are similar to those in eutrophic lakes in southern Saskatchewan.

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APPENDIX 1

TRACE ELEMENT CONCENTRATIONS IN SITE 1 SOIL

APPENDIX 1

TRACE ELEMENT CONCENTRATIONS IN SITE 1 SOIL

Parameter (ug/g dry wt. or %)		Field Plots 1	2	3	4	5	6	7	8	9	10	11	12	13	Median
Al	%	6.35	6.33	5.91	6.08	6.48	6.24	6.06	6.40	6.14	5.95	6.10	6.21	4.58	6.14
		6.23	6.42	5.42	6.27	6.67	6.49	6.77	6.36	6.21	5.94	6.15	6.28	4.15	6.27
As		11	24	9	8	17	12	14	21	<3	<3	<3	20	8	11
		37	10	1.5	17	12	17	13	<3	<3	9	28	24	16	13
B		<6	10	<6	33	<6	<6	<6	25	12	<6	<6	17	31	<6
		<6	<6	<6	15	14	3	3	3	10	90	85	11	<6	<6
Ca	%	1.6	1.65	1.63	1.23	1.58	1.21	1.58	0.961	1.32	1.85	1.86	1.7	6.21	1.6
		1.6	1.72	2.75	1.69	1.27	1.33	0.99	1.18	1.55	1.22	1.71	1.82	7.34	1.6
Cd		<1	<1	<1	<1	<1	<1	<1	<1	7	7	5	5	<1	<1
		<1	<1	5	<1	<1	<1	3	3	4	10	5	4	<1	3
Co		12	431	13	14	17	13	10	12	17	14	123	15	<1	14
		15	13	13	11	13	15	13	16	26	21	15	14	<1	14
Cr		71	84	76	43	109	52	95	72	112	106	127	243	348	95
		77	71	108	68	77	92	60	152	146	256	218	265	167	108
Cu		<5	<5	<5	<5	<5	<5	<5	<5	45	41	40	23	41	<5
		<5	<5	23	<5	<5	<5	<5	26	<5	22	17	25	54	<5
Fe	%	2.99	3.02	2.78	2.88	3.17	2.98	2.91	3.05	2.95	2.89	2.92	2.96	2.3	2.95
		2.98	3.03	2.61	2.99	3.23	3.09	3.27	3.05	2.97	2.83	2.96	3.01	1.97	2.99
Hg		<3	<3	<3	14	<3	<3	<3	15	4	<3	<3	<3	<3	<3
		10	<3	<3	<3	<3	<3	<3	<3	<3	41	7	3	<3	<3
K		7620	8600	7800	7970	8750	8100	9270	9570	8220	8500	7850	8050	5820	8100
		7750	8150	7750	8100	9270	9000	10200	9400	8520	7770	8200	8220	5350	8200

APPENDIX 1 (continued)

Parameter (ug/g dry wt. or %)		Field Plots 1	2	3	4	5	6	7	8	9	10	11	12	13	Median
Mg	%	1.08	1.07	0.995	0.935	1.22	1.15	1.16	0.97	1.06	1.17	1.21	1.13	1.41	1.13
		1.09	1.09	1.16	1.08	1.17	1.14	1.16	1.09	1.11	1.01	1.19	1.21	1.48	1.14
Mn		565	564	562	605	581	606	626	650	619	572	626	577	1526	605
		568	584	539	589	585	597	599	650	578	597	643	609	1651	597
Mo		1	<1	<1	1	2	<1	1	1	2	1	1	1	3	1
		3	1	1	1	<1	<1	<1	1	2	3	1	2	<1	1
Na		700	770	820	700	670	1300	920	550	670	1070	700	850	1150	770
		500	670	600	420	770	670	550	520	650	550	700	950	600	600
Ni		124	101	92	101	139	110	119	109	181	155	147	137	135	124
		172	104	179	113	108	145	125	194	221	366	147	121	113	145
Pb		14	11	16	14	10	25	9	16	11	13	9	11	21	13
		15	11	23	11	9	14	13	10	8	11	13	12	6	11
Se		<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
		<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Si	%	22.5	21.9	22.7	22.6	21.3	22.1	21.9	22.7	22.4	22.0	22.0	22.4	18.1	22.1
		22.4	22.0	22.1	22.4	22.0	21.8	22.4	22.1	22.3	22.3	21.8	21.1	17.5	22.1
U		1	1	1	2	1	2	1	1	1	2	1	<1	4	1
		1	1	1	1	<1	2	1	1	1	2	<1	1	4	1
V		121	119	112	106	119	112	116	120	<10	<10	<10	173	141	116
		114	121	<10	115	129	137	126	<10	<10	126	225	279	124	124
Zn		<5	<5	<5	<5	<5	<5	<5	<5	412	239	492	104	<5	<5
		<5	<5	135	<5	<5	358	<5	231	148	116	107	111	<5	107

APPENDIX 2

TRACE ELEMENT CONCENTRATIONS IN SITE 2 SOIL

APPENDIX 2

TRACE ELEMENT CONCENTRATIONS IN SITE 2 SOIL[a]

Trace Element	Transects						
	1	2	3	4	5	6	Median
As	10.6	10.6	11.1	10.6	11.0	10.8	10.7
Cd	<2	<2	<2	<2	<2	<2	<2
Co	11.4	13.8	14.4	13.8	13.7	14.6	13.8
Cr	99.9	96.9	105.7	101.7	99.6	94.7	99.8
Cu	31.7	32.3	32.2	32.5	31.8	32.4	32.3
Hg	0.012	0.016	0.018	0.015	0.034	0.012	0.016
Ni	34.9	35.95	34.6	31.5	30.3	32.2	33.4
Pb	15.7	14.55	12.9	13.2	12.2	13.1	13.2
Se	0.68	0.69	0.61	0.58	0.5	0.62	0.62
Zn	110.5	114.8	112.1	115.1	111.3	116.0	113.5

a (ug/g dry wt.)